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THE FOURTH INDUSTRIAL REVOLUTION AND ITS IMPACT ON THE FIELD OF INDUSTRIAL DESIGN

NGO THI THU TRANG

Industrial Art Faculty, University of Architecture Ho Chi Minh City, Vietnam

ABSTRACT

It's hard to deny that the fourth industrial revolution has taken place all over the world. It has changed many modes of human activities including manufacturing, trading, shopping, consuming and interacting. Recently, the term Industrial 4.0 has been mentioned many times. The fourth industrial revolution has not only impacted the manufacturing and business sectors, but also influenced and comprehensively changed people's lives. It is reshaping the economic, social, cultural and humanistic environment in which we live. It not only changes what we are doing, how we do it, but also who we are. (Klaus Schwab - Founder and CEO, World Economic Forum) [1]. By explaining the influences of Industrial 4.0's major technologies on the manufacturing industry, the article brought out the impacts of the fourth industrial revolution on the field of Industrial Design, from design methodologies to working platform and the role of a designer. Finally, based on these changes, the article proposes new knowledge and skills to update the content of industrial design education.

KEYWORDS: Fourth Industrial Revolution, Industrial 4.0, Technologies, Industrial Design, Manufacturing Industry & Education

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Original Article

INTRODUCTION OF INDUSTRIAL 4.0

The term Industrial 4.0 was popularized by a German agenda on digital technology in 2009. The author of the agenda, Henrik von Scheel, described Industrial 4.0 as a movement that would change every industry in today's world. However, according to the author, the focus of Industrial 4.0 was not about technology, but how humans connected and worked together [2].

In present days, Industrial 4.0 has become a global concept, although every part of the world will tend to focus on some certain aspects of it, with different forms and names. For example, Alan Norbury (Siemens Industrial CTO) noted that Industrial 4.0 was characterized by the big data system, the Internet of Things, smart algorithms, robotics, 3D printing, virtual reality and augmented reality technology, and the cyber-physical systems [3]. According to Mark Cotteleer and Brenna Sniderman, in addition to the above features, Industrial 4.0 was also demonstrated through smart, connected technology embedded into organizations, assets and even people, and it was marked by the emergence of artificial intelligence and cognitive technology, nanotechnology, quantum computing, internet-connected wearable, and advanced materials [4].

Compared to its start in the manufacturing industry, Industrial 4.0 has now surpassed the scope of factories, expanding its influence over the ecosystem of all stakeholders involved within a product's life cycle, ranging from manufacturers, designers, suppliers, distributors to buyers and consumers.

CHANGES IN INDUSTRIAL PRODUCTION UNDER THE INFLUENCE OF TECHNOLOGIES IN THE FOURTH INDUSTRIAL REVOLUTION

In order to understand the effects of the fourth revolution on Industrial Design, we first need to understand how its impacts have changed the industrial production.

According to the Boston Consulting Group, there are 09 technologies in the Industrial 4.0 that had transformed industrial production around the world, including: Big data and analytics, autonomous robots, simulation of physical reality through computers, the industrial Internet of Things, cyber security, sharing information via cloud technology, additive manufacturing, and augmented reality [5]. So on what aspects of industrial production are these technologies impacting?

Production

- The simulation of the physical world into a virtual computer model (digital twin) helps manufacturers understand and foresee problems potentially arising from the working system to the operation of test products, equipment and even their employees, thereby reducing risks and increasing operational efficiency.
- Autonomous robots used in production will replace the work of manual laborers. This will lead to manufacturers currently hiring manual laborers from developing countries to stop this activity, because it is no longer needed.
- Additive manufacturing technology, such as 3D printing, will help accelerate and cut down the costs in different steps of design and production. Specifically, 3D printing of prototype product allows combining multiple complicated components of a single product in one print, which will reduce the time and effort to assemble the final product. In addition, it also allows producing products in small quantities by order without the mold-making cost as with previous models of production. Additive shaping method also reduces the waste of raw materials by 100%, comparing to conventional methods such as carving off materials to shape the final product. Currently, additive manufacturing has been used in the production process of many industries, such as aerospace, defense, machinery, automobile, to consumer products, toys, shoes, medical tools, and even architecture and construction[6].

Products and Services

- The use of big data technology and analytics, Internet of Things and sharing information via cloud technology helps connect manufacturers, supply chain system, and distribution system to consumers and even to each product sold, by attaching sensor devices to each product. This makes it possible for businesses to better understand the consumption of products, thereby making predictions to release new products faster and with better designs.
- Moreover, the data collected through these connecting technologies will become very important for businesses; therefore it will become commercial good or create new services. Even the sale of services and software (such as mobile applications) then creates a source of revenue that is more sustainable and more valuable than the sale of physical products.
- 3D printing technology allows manufacturers to provide highly personalized products, manufactured according to the individual requirements of each customer. As the nature of this type of production is essentially data in the

computer, by just changing the size data in the computer, they can create a new product. Consequently, it also allows manufacturers to change product models with faster cycles or expand product lines at lower costs.

Supply-Chain

- Connected technologies help smart factories connect seamlessly with supply-chain networks, from materials, equipment, accessories to logistics capabilities, not only reducing the risk of supply shortage, but also facilitate producers to find the most profitable suppliers. The connection between distributors and customers also lets manufacturers predict and stock up accessories for customers to replace when necessary.
- 3D printing technology enables manufacturers to quickly provide components and accessories based on customer requirements. They can also reach remote areas, as the products can be printed on the spot with a Compact 3D printer. Furthermore, the ability to print products at the point of sales helps manufacturers expand their markets at relatively low costs.
- Virtual reality technology, with the display of eye-wear devices, will help customers experience products online via the internet to easily select products or services. According to statistics, 90% of B2B buyers now use online systems on the internet to search for industrial products, and nearly 60% of purchases have been made without physical contact with a salesman. [7]

Customer Relationship

- The use of Internet of Things and sharing information via cloud technology helps bring information from manufacturers straight to end users so that they can interact continuously and even provide their own suggestions to adjust the product design. In addition, after-sales support services will also be made easier and better.
- With the application of the3D printing technology, users now have the ability to design their own products.
- Augmented reality technology, through smart phones or smart glasses' display, will help customers easily understand how to use the product and its features even when it is a complex integrated product.
- In the age of Industrial 4.0, users are not only interested in the physical product itself, but also in the analyzed information and customized applications installed in the product.

To make it easier to relate the factors listed above, Table 1 below summarizes the changes in the aspects of production, products & services, supply chain and customer relationship in the industrial production under the influence of technology in the fourth revolution.

Table 1: Summary of the Changes in the Aspects of Production, Products & Services, Supply Chain and Customer Relationship in the Industrial Production under the Influence of Technology in the Fourth Revolution

Technology	Production Activity	Product	Supply Chain Activity	Customer Relationship
Big data technology and analytics Sharing information via cloud technology Internet of Things	Artificial intelligence analyzes information and makes quick management decisions	• Quickly provide products to meet requirements • Create new services • Switch focus from selling products to selling data collected from products, services and application software	• Quick and efficient supply chain • Always stock components and accessories per customer's demand	• Customers participate in different activities, including the design process • After-sales support services are more available • Information is analyzed and applications within the product become the main point of interest

Table 1 Contd.,				
Autonomous robots	Reduce manual laborers and revoke this operation in developing countries	Precise, less mistakes		
Simulation	Increase the efficiency of the working system, product, equipment and employees	Quickly release new products	Increase online sales via the internet	Experience products online via the internet
Additive manufacturing	• Accelerate the design process • Reduce assembling time • Produce in smaller quantities • Reduce material waste	• Provide highly personalized products • Change up product models and quickly expand product lines	• Quickly provide components and accessories by request, even to remote areas • Cut down on intermediaries • Expand markets in remote areas	Users are allowed to design products by their own reference
Augmented reality			Increase online sales via the internet	Easily understand features of a complex product

IMPACTS OF THE FOURTH REVOLUTION ON THE INDUSTRIAL DESIGN FIELD

Industrial Design is a field within Applied Arts and is closely related to industrial production. Industrial Design is a creative process of creating new ideas for a product and developing this idea into a design that meets market requirements, production techniques, and then it will be manufactured into the final product. Therefore, the changes that take place in different aspects of the industrial production industry (as stated in Section 2) will also greatly affect the work of Industrial Design and even alter the role of the designer within the Industrial Design process. In other words, Industrial 4.0 has transformed the way a product is designed, manufactured, purchased, delivered, used and maintained, which are almost all phases of a product's life cycle - all are within the scope of interest for Industrial Design.

Expanding the Scope of Design and Changing the Design Mindset

First of all, computer software effectively accelerates the design process from forming aesthetics to calculating the composition of different components. Smart algorithms and artificial intelligence also help search from thousands of solutions in data to provide suggestions in a short time, something the human brain can hardly do. As well, making prototypes with 3D printing technology and running sample tests through simulation and virtual reality technology shorten the time to test designs.

Among the typical technologies of Industrial 4.0, it can be said that additive manufacturing (such as 3D printing) has the most influence on Industrial Design. In addition to producing prototypes, many businesses now use this technology to print products for end-users due to its many advantages in terms of production and business as stated in Section 2. In this section, the article will focus on the advantages created by additive manufacturing for design activities. In terms of techniques, simply speaking, additive manufacturing is a form of printing overlapping layers on each other, so it allows to create closed empty spaces within the object - something that is difficult to do with conventional methods such as casting (for metals, plastics, ceramics ...) or gradual carving (for wood, stone ...). Due to this factor, additive manufacturing opens up new possibilities in design as follows:

- Creating lighter materials: Due to the ability to create gaps inside the materials' sheets, it will make the materials lighter but still strong enough. As a result, products using such materials will be lighter than those using solid

materials. Diametal, a Swiss company, has used additive technology to manufacture its machinery parts. These parts have reduced their weight by 75% compared to previous methods [8].

- Freely creating shapes: Thanks to the method of adding temporary supporting materials during printing, additive manufacturing allows designers to create any shape, even interlacing extremely complex and unique shapes together.
- Simplifying composition in structure: Thanks to the method of using temporary support materials, additive manufacturing technology also allows simultaneously printing many components integrated into each other, thus reducing the number of parts to be assembled with screws later on. For example, the dress designed by Nervous System has lots of details connected to each other but was printed in a single time, like a piece of cloth (Figure 1).
- Easily installing sensor devices into products, increasing usability: Simply by creating empty spaces inside the product, 3D printing technology allows more sensors to be installed into the spaces during printing and encapsulating [9]. These devices will help designers create many new usages for the product.
- Personalizing each design: Additive manufacturing is essentially a form of printing products based on data from a computer, as stated in Section 2 of the article, and thus it allows the adjustment of the design directly on the computer and printing the new product without the mold-making cost as with traditional methods. As a result, designers will no longer need to worry too much about the technical requirements for production. Instead, they now can focus more on creating more suitable, convenient designs for each user. Currently, shoe manufacturers are applying 3D printing technology to create shoe soles according to the foot structure of each person.
- Increasing demand for design: Because changing new models is now easy, fast and at a relatively low cost, business will have the need to offer more new models to attract customers, resulting in increasing demand for new designs.

Figure 1: 3D Printing Dress, Designed by Nervous System [10]

Nanotechnology is now gradually being applied to the materials industry to create metamaterials (such as graphene, which is 200 times harder than steel and millions of times thinner than human hair [11]), smart materials that has the ability to respond to impacts from the external environment or possesses properties that cannot

be found in naturally occurring materials. These new materials will help designers create lighter, more flexible and smarter products, opening up new visions.

In addition, virtual reality technology, augmented reality and connected technology are now opening up a new horizon for designing internet-connected wearable such as smart watches (like Apple watch), smart glasses (like Google glasses), ear-wear devices, phones integrated into the body, etc. Gartner's research and consulting team estimated that 514 million smart watches and hand-wear products will be sold by 2020 [12].

Virtual reality technology and simulation technology not only support end users, but also help designers experience their own designs to adjust and change design details for easier use, making the product more convenient and attractive without having to produce a sample product.

With the explosion of smart products and artificial intelligence, interactions between users and products will gradually shift to by eyes and voice. Eye-tracking devices will turn the eyes into the source for interaction and feedback, transforming vision into an instant interface. Based on this fact, product designers also need to redirect their research to elements that allow product interaction and control by vision and voice instead of applying design principles of hand interaction. This will also make the product's shape simpler and include less detail for control.

Another manifestation of the fourth industrial revolution is the emergence of platform-based community service businesses, such as Grab, Uber, Airbnb, etc. Thanks to the connected technology of Industrial 4.0, these new business models create a global platform that connects people with physical products to those who want to use them. The core business for these companies is actually a service, not a product. With this trend, more and more consumers no longer buy and own tangible products but pay for the services they use through a digital platform. This is also a point that designers need to think about when designing a product: can this product be used in a community-based service? From that, a new design direction is opened up: designing for services. This design direction will require a different, more holistic approach.

Changing the Working Method and the Role of the Designer

The impact of the fourth revolution not only opens up new broader horizons for the field of Industrial Design but also changes the role of the designer in the process of creating new products.

First of all, as discussed above, the connected technology of Industrial 4.0 now allows all information among stakeholders involved in a product's life cycle to be shared clearly and instantly. The relationship between manufacturers and customers is also increasingly close and direct, leaving out intermediaries. This will lead to a major change in the working method of the designer, creating an open source design. Simply speaking, if manufacturers previously had to hire an entire design team to work for the company, they can now search, choose and buy designs on globally connected platforms with extremely diverse design sources. As a result, designers will have more opportunities to work freelance instead of being tied up with one business. Their designs will also have the chance to go beyond a country to be produced and used in other places around the world.

Another impact of Industrial 4.0 is the democratization of creative activities. Some businesses take advantage of openly sharing information with their customers to get feedback for design adjustments directly from them or even open design competitions for customers to crowd source ideas for new products [13]. Symmons, a manufacturer of bathroom

equipment, has created a direct channel of interaction with customers in the design process of door handles and faucets. The company used the results of this collaboration to develop new products according to customer requirements [14].

Figure 2: Sketch Furniture, Designed by Front Studio

Moreover, with the convenience and ease of additive manufacturing technology, many businesses have developed strategies to increase interaction and connection with customers by asking and allowing them to design products based on their preference. For example, in the toy industry, Blizzard Entertainment took advantage of 3D printing technology to let customers adjust the design of characters in their online video games. These personalized characters would then be printed by 3D printing and delivered to customers [15]. Siemens is currently applying 3D scanning and 3D printing technology to mass produce more than ten million hearing aids based on individual ear structures [16]. In these cases, the role of the designer will no longer focus on building ideas but shifting to managing the design templates and supporting the customer in the interactive designing process by offering their professional advice and consultation. Designers can also design tools and devices to help customers (who have no expertise in design) shape the product more easily. On the other hand, as seen in the design of sketch furniture by Front Studio (Figure 2), here the designers created a pen device to help users draw the objects they want in a real space through the display of computer software, and then the design file will be transferred to a 3D printer and turned into a real product. Theoretically, customers can even buy designs and print the products at home. It is estimated that buying the right to produce a product at home saves 80%-90% of the cost comparing to buying products at retail stores [17].

Changes in the scope of design, mindset and role of designers under the influence of technologies from the fourth revolution are summarized in the Table 2 below.

Table 2: Changes in the Field of Industrial Design under the Influence of Technologies from the Fourth Revolution

Technology	Scope of Design	Design Mindset	Role of Designers
Big data technology and analytics Sharing information via cloud technology Internet of Things	• Applicable in many countries around the world • More options for technology and materials • New usages for the product (providing analytical information services)	• Collaborate with customers in the design process • Design for services	• Open source for designs • Democratize design activities • Shift part of the designer's role to customers • Designers are tasked to support customers during the design process

Table 2 Contd.,			
Nanotechnology	Products are lighter, smarter and more flexible	Update nanotechnology's application in product design	
Simulation	Designs are experienced and adjusted quickly		
Additive manufacturing	• Lighter materials • Create shapes freely • Simplified compositions • New usages • Personalized design	Focus more on creating designs that are more suitable and convenient for individual users	• Sell designs directly to users • Increasing demand for new designs
Virtual reality and augmented reality	• Add in more interesting features • Internet-connected wearable • Products have simplified details	Eyes become the means of interaction	Democratize design activities

SUGGESTIONS TO IMPROVE EDUCATION CONTENT FOR THE FIELD OF INDUSTRIAL DESIGN

As the requirements in design, mindset and role of the Industrial Design sector had shifted under the impacts of the fourth revolution, Industrial Design practitioners in general and Industrial Design training institutions specifically need to immediately take preparatory steps to catch up with the new demands in production, economy and society.

From the changes presented in Table 2, the following table will present suggestions for the addition of new knowledge, skills and methods in the training for the Industrial Design practice.

Table 3: Changes in the Field of Industrial Design under the Influence of Technology in the Fourth Revolution

Technology	Changes in Industrial Design	Additional Training Content
Big data technology and analytics	• Applicable in many countries around the world • More options for technology and materials • New usages for products • Collaborate with customers in the design process • Design for services • Democratize design activities • Designers in a supporting role	• Knowledge of connected technology • Skills to find information or sell designs via connected platforms • Skills to collaborate with customers in the design process • Social skills • Methods of design for services • Project management skills • Knowledge and methods to design for customer experience
Sharing information via cloud technology		
Internet of Things		
Nanotechnology	• Materials are lighter, smarter and more flexible	• Skills to search for and apply new material technology
Simulation	• Designs are experienced and adjusted quickly	• Knowledge of simulation technology
Additive manufacturing	• Lighter materials • Create shapes freely • Simplified compositions • New usages • Personalized designs • Focus more on creating designs that are more suitable and convenient for individual users • Sell designs directly to users • Increase demand for new designs	• Knowledge of additive manufacturing • New shaping methods to fit with additive manufacturing • Methods to personalize designs • Skills to apply additive manufacturing into accelerating new product design process

Virtual reality and augmented reality	• Add in more interesting features • Internet-connected wearable • The eyes become the means of interaction	• Knowledge of virtual reality and augmented reality • Methods to create interactive designs • Knowledge of anthropometrics to design eyes and voice interaction

Table 3 showed that in order to respond to the changes in the field of Industrial Design, new knowledge should be provided to students studying Industrial Design, especially knowledge of the technologies developed in the fourth revolution and new design methods to satisfy the work's requirements, including:

- Knowledge of connected technology, simulation technology, additive manufacturing, virtual reality and augmented reality
- Knowledge and method of design for user experience, services and interaction
- Methods to personalize designs
- Knowledge of anthropometrics to design eyes and voice interaction
- New shaping methods to fit with additive manufacturing
- Along with updating new knowledge, some other skills should also be added as followed:
- Skills to find information or sell designs through connected platforms
- Skills to find and apply new materials technology
- Skills to collaborate with customers in the design process, social skills, project management skills
- Skills to apply additive manufacturing technology into accelerating new product design process

According to a study in The Future of Jobs Report (Word Economics Forum), in the near future, careers with a low risk of being replaced by machines will be ones requiring social and creative skills; especially the ability to make decisions in the context of changes and the development of a plethora of new ideas [18]. Therefore, it is essential for Industrial Design students to focus on learning the skills mentioned above.

CONCLUSIONS

By analyzing of the impacts of the fourth revolution on industrial production and the field of Industrial Design, the article showed great potentials for this group of technologies. The speed of technological development in this revolution is extremely fast. For example, just over ten years ago, 3D printing technology was only used to create draft models in hard plastics. Nowadays, 3D printers are able to print out finished products with a full range of diverse materials, even using cells to print human body parts. Although this article has just provided predictive information about the scope of influences in the future based on data that has begun to appear in present days, however, with such a growth rate, soon these technologies will reshape the entire industrial production of today. The role of an Industrial Design designer in the process from design to production will also transform greatly. Therefore, as educators in this field, we need to quickly update new mindset and perspectives for students, preparing them to adapt to major changes in the future. Updating knowledge to create a new generation of designers that can meet the requirements and further accelerate this transformation is a must-do from today.

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